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Simulation of Cereal Growth - Some Results for Winter Wheat

Agricultural memorandum 892 proposed a simulation model for cereal growth and applied it to data for spring barley at Sutton Bonington and for winter wheat at Bridget's EHF. Four years of data on winter wheat growth are now available from Sutton Bonington and the model has been run for comparison against these. The data on wheat growth are very detailed and include weekly measurements of crop dry weight and leaf area index from January to harvest usually.

Meteorological data were from the standard climatological station at Sutton Bonington (maximum and minimum air temperature, rainfall, number of days with 1 mm rainfall or more and sunshine hours) or from tables (daylength and RA (see eq (6) in Ag. Memo 892)). Potential transpiration was estimated by using the 'sunshine correction' method for which see MAFF Technical Bulletin 35. All the weather data were averaged over weekly periods beginning in early April, but in early February in 1976 when the crop was well advanced by the mild winter. The average leaf area index for these weekly periods was estimated from a smooth curve joining the points on a LAI-time graph.

Results

The results are for the years 1974 to 1977 with one trial per year except in 1976 when there was one trial with 'normal' treatment and another with 'no nitrogen'. In each year the calculated and observed dry matter yields are plotted together with the leaf area index.

1974

The observed total dry weight in fact did not include the weight of roots. The dashed line is an estimated (tops + roots) dry weight at the end of the growing season. This year was cool, dull and with plenty of rain in June. The model crop grows too fast in April, but the rate of growth is near the observed rate in May and June. Both the real and the model crop lose dry weight at the end, possibly not for the same reason.

1975

This summer was warmer, with more sunshine and less rain than 1974. Soil water became in short supply by the end of June, and heavy rain in mid-July was too late to be used usefully. The model crop grew very fast in April and by chance gave the same dry weight as the real crop at the end of April. Thereafter the real and model crops had similar growth rates so that the agreement was quite good.

1976

Both the winter and summer were unusually warm which caused the crop to increase in dry weight throughout the winter and ripen about 3 weeks before the normal harvest date. Severe water stress developed by the end of June. For the 'normal' treatment the model crop grew too fast between February and April so that by early May the model crop weighed 6.8 t/ha against the real crop of 3.3 t/ha. Growth

rates in May were similar. The model crop ceased to assimilate by mid-June and lost dry weight afterwards when the real crop was still growing.

A similar pattern occurred for the 'no nitrogen' treatment. The model crop grew too fast in February, March and April; it was not until May that the rate of growth of the real crop was about the same as the model crop. By the end of May the model crop was 3.5 t/ha heavier. However, the model crop ceased to assimilate in mid-June and lost dry weight afterwards when the real crop was still growing.

1977

The summer was mainly cool with ample rain in June. July was drier and moderate water stress developed a few weeks before harvest. The growth rate in April and early May was higher for the model than for the real crop. Agreement was better in the second half of May, but then became somewhat worse again in June. By mid-July the model crop had stopped assimilating while the real crop continued to grow.

Comments

This four years of data show obvious faults in the model. The two most serious differences between the model crop and the real crop occur in spring when the model crop grows too fast, and a few weeks before the end of the growing season when the model crop stops growing and loses dry weight while the real crop is still growing.

Spring Growth

Some possible reasons are:-

1. Temperature is restricting photosynthesis rates. The daytime temperature ranged from 2°C in February 1976 to 7-10°C in most Aprils. Very little precise data about temperature and photosynthesis rates seems to be available and most authors suggest that for temperate cereals the net photosynthesis is approximately constant between 10 and 25°C with a decline below 10°C to very low rates around 0°C. Therefore in 1976 in particular, the model photosynthesis rates could be much larger than the real ones. Daytime temperatures of 8-12°C in May do not seem to impede growth since the model and observed crop growth rates are nearly equal.

2. The environment during leaf growth may affect photosynthetic capacity. Leaves which photosynthesise in March and April have grown in February and March under conditions of short days, low light intensity and lower temperatures. The photosynthetic rates used in the model were from leaves which grew in May and June.

3. The light interception factor S, which is a characteristic of canopy architecture, may vary during growth. A value of S = 0.7 is used at all times during the growth of the crop, which is a value obtained from measurements of light interception made in June and July. It is possible that leaves in March and April are more erect and therefore the canopy interception of light is lower than the model suggests. In Ag. Memo 892 some simulations were performed with S = 0.8 which resulted in about a 10% reduction of crop growth rate.

The observed and model rates are about the same when the leaf area index exceeds about 2. However, in 1976 (nitrogen treatment) equal rates of growth were not reached until the LAI reached 3.4. This may relate to the change in the value of S mentioned above, or it could be because the model works best when the canopy is absorbing most of the incident light falling on it.

End of Season Growth

The large losses in dry weight for the model crop which take place two to four weeks before the LAI declines to zero have been mentioned before in Ag Memo 892 as being due to high respiration losses. The fault is thought to be because in the model all the dry weight contributes towards maintenance respiration whereas in fact there is a steady drop in the proportion of live to dead tissue as the crop ages. In four out of the five examples the real crops also lost weight, but the losses occurred later than for the model crop and were of smaller size.

The effect may be worse with the model due to the higher dry weights reached by the early summer. This implies a high maintenance respiration load which would balance gross photosynthesis at an earlier date. The problem may therefore become less if the spring growth is modelled correctly.

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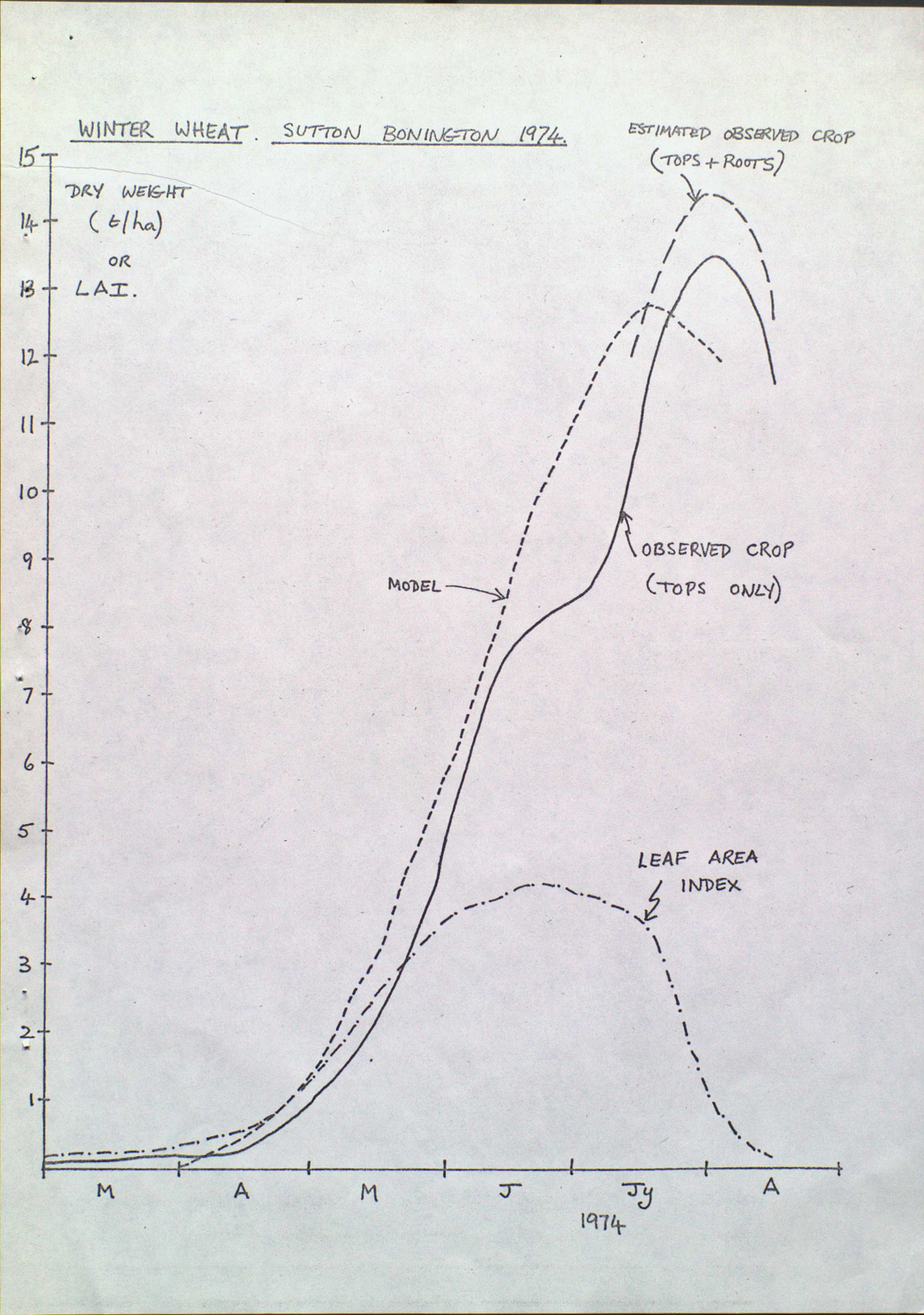
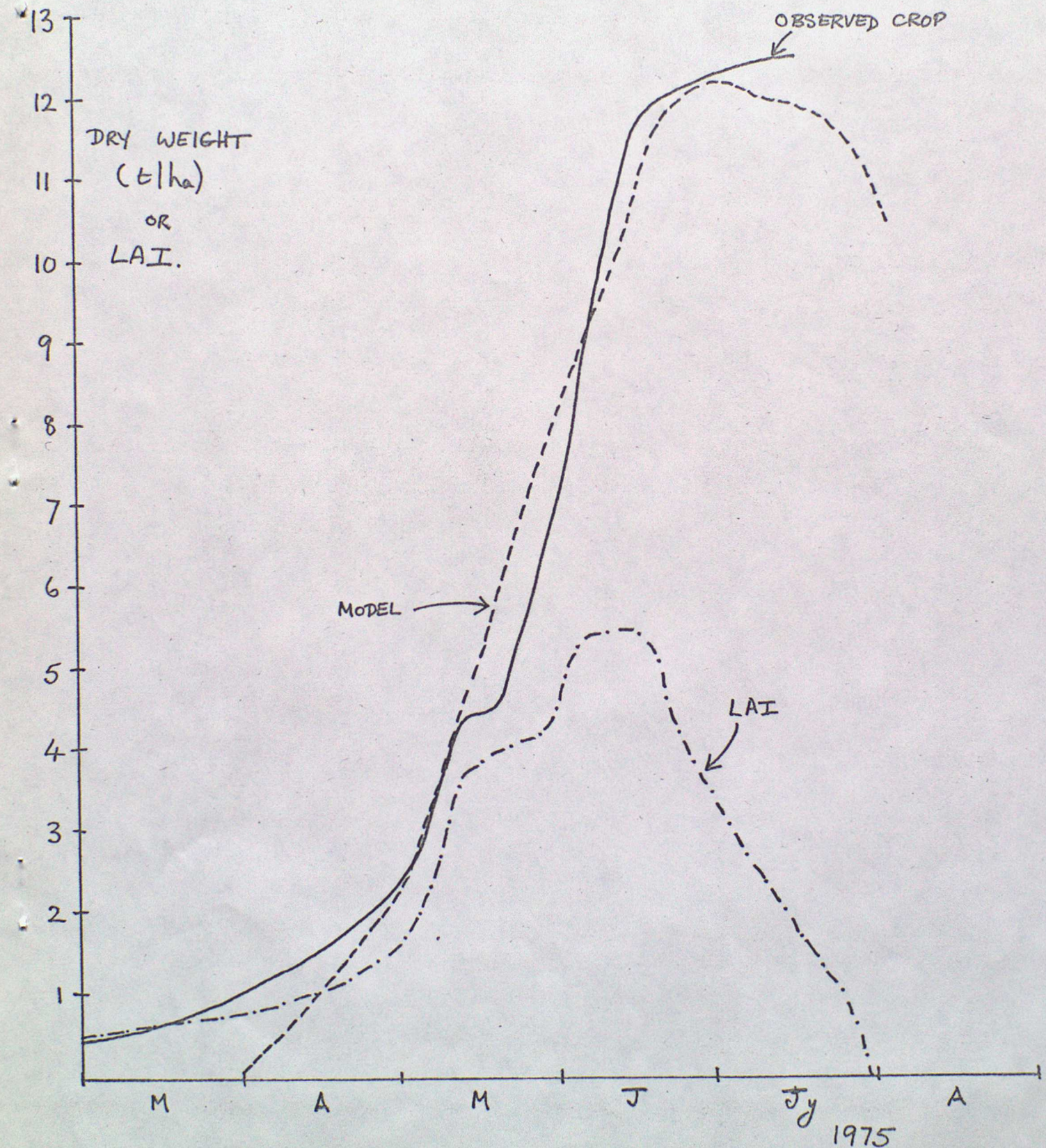
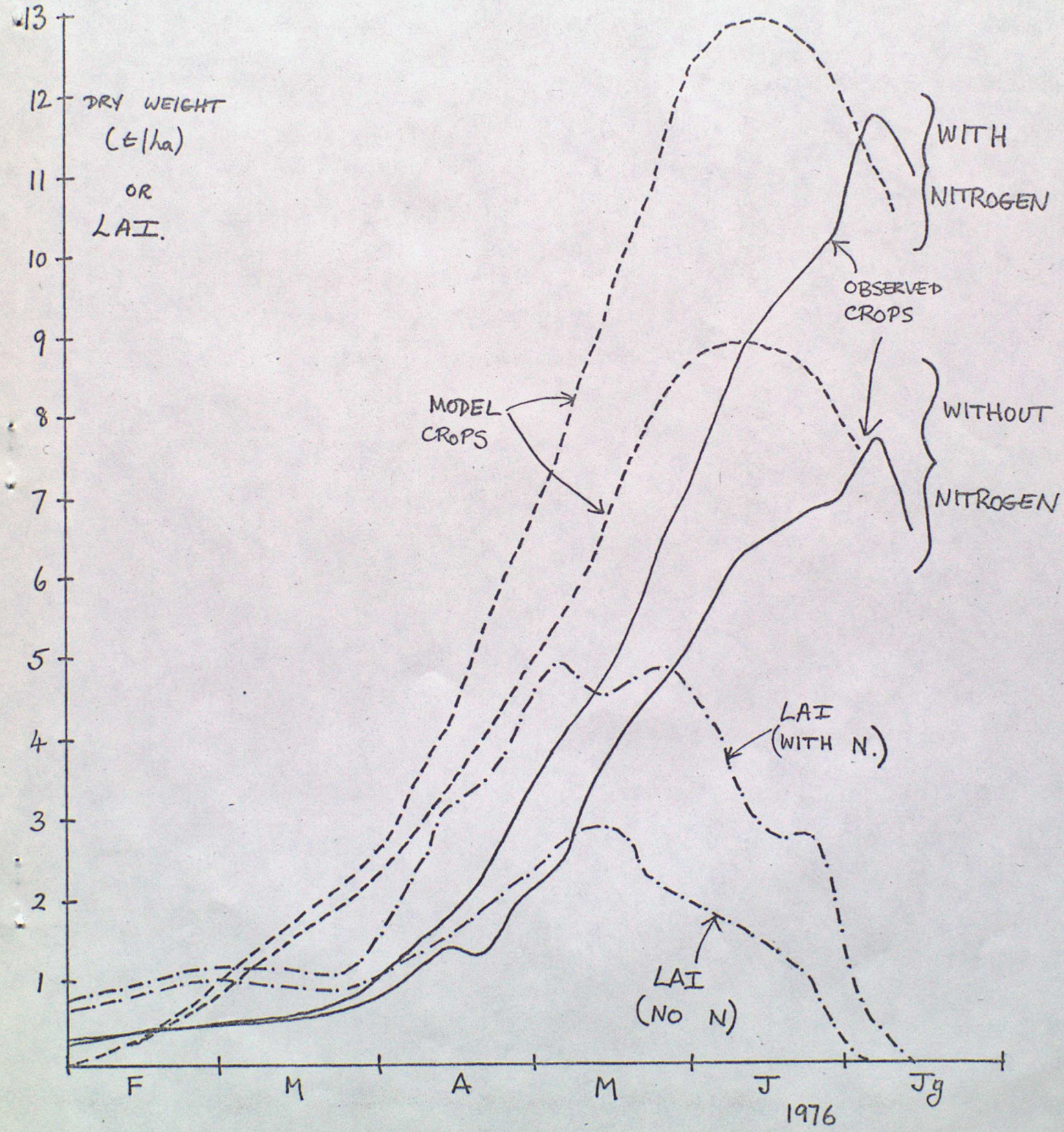

WINTER WHEAT. SUTTON BONINGTON 1974.
ESTIMATED OBSERVED CROP
(TOPS + ROOTS)
DRY WEIGHT
(t/ha)
OR
LAI.
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
MODEL
OBSERVED CROP
(TOPS ONLY)
LEAF AREA
INDEX
M
A
M
J
Jy
A
1974

WINTER WHEAT. SUTTON BONINGTON 1975.



WINTER WHEAT. SUTTON BONINGTON 1976.



WINTER WHEAT. SUTTON BONINGTON 1977.